(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 830 496 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
05.03.2003 Bulletin 2003/10

(21) Application number: **96915488.9**

(22) Date of filing: **02.05.1996**

(51) Int Cl.[7]: **F01L 9/02**, F01L 9/04

(86) International application number:
PCT/US96/06256

(87) International publication number:
WO 96/036795 (21.11.1996 Gazette 1996/51)

(54) A HYDRAULIC ACTUATOR FOR AN INTERNAL COMBUSTION ENGINE

EIN HYDRAULISCHES STELLGLIED FÜR EINE BRENNKRAFTMASCHINE

ACTIONNEUR HYDRAULIQUE POUR MOTEUR THERMIQUE

(84) Designated Contracting States:
DE FR IT

(30) Priority: **17.05.1995 US 442665**

(43) Date of publication of application:
25.03.1998 Bulletin 1998/13

(60) Divisional application:
02004847.6 / 1 245 798

(73) Proprietor: **Sturman Industries, Inc.**
Woodland Park, CO 80863 (US)

(72) Inventor: **STURMAN, Oded, E.**
Woodland Park, Colorado 80863 (US)

(74) Representative: **Gilmour, David Cedric Franklyn**
POTTS, KERR & CO.
15 Hamilton Square
Birkenhead Merseyside CH41 6BR (GB)

(56) References cited:
WO-A-93/01399
FR-A- 1 361 178
US-A- 5 069 422
US-A- 5 327 856
US-A- 5 339 777

EP 0 830 496 B1

Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] The present invention relates to a hydraulically controlled valve applicable as an intake or exhaust valve for an internal combustion engine, such as known from WO-A-93/01399.

2. DESCRIPTION OF RELATED ART

[0002] Internal combustion engines contain an intake valve and an exhaust valve for each cylinder of the engine. In a compression ignition (CI) engine the intake valve allows air to flow into the combustion chamber and the exhaust valve allows the combusted air/fuel mixture to flow out of the chamber. The timing of the valves must correspond to the motion of the piston and the injection of fuel into the chamber. Conventional CI engines incorporate cams to coordinate the timing of the valves with the piston and the fuel injector. Cams are subject to wear which may affect the timing of the valves. Additionally, cams are not amenable to variations in the valve timing during the operation of the engine.

[0003] The exhaust valve of a internal combustion engine is opened for the exhaust stroke of the engine cycle. Before the exhaust valve is opened, there is a differential pressure across the valve equal to the difference between the pressure of the exhaust gas within the combustion chamber and the pressure within the exhaust manifold. The force required to open the valve must be large enough to overcome this differential pressure. When the valve is initially opened, the exhaust gas flows out of the combustion chamber and rapidly reduces the pressure within the chamber. After the exhaust valve is initially opened, the force that continues to open the valve is generally much larger than the energy required to overcome the gas pressure within the chamber. This additional work ultimately lowers the energy efficiency of the engine. The lost energy can be significant when multiplied by the number of exhaust strokes performed by an engine. It would therefore be desirable to provide an exhaust valve assembly that optimizes the opening force of the valve.

SUMMARY OF THE INVENTION

[0004] The object of the present invention is to avoid the drawbacks of the prior art, this object being achieved by a valve assembly according to claim 1 and a method according to claim 7.

[0005] The present invention is thus a camless intake/exhaust valve for an internal combustion engine that is opened by a plurality of pins. One of the pins engages a stop so that the valve is initially opened with a relatively high force and then moved into the fully opened position with a lower force.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The objects and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, wherein:

Figure 1 is a side cross-sectional view of an alternate embodiment of an intake valve with a plurality of pins that open the valve;
Figure 2 is a cross-sectional view similar to Fig. 6, showing one of the pins engaging a stop;
Figure 3 is a side cross-sectional view of an alternate embodiment of the intake valve of Fig. 6, showing a four-way actuating valve.

DETAILED DESCRIPTION OF THE INVENTION

[0007] Referring to the drawings more particularly by reference numbers, Figure 1 shows a valve assembly 150 of the present invention. The valve assembly 150 is typically incorporated into an internal combustion engine as either an intake or exhaust valve. The assembly 150 has a valve 156 that includes a seat located at the end of a valve stem. The seat is located within an opening in the internal combustion chamber of the engine. The valve 156 can move between an open position and a closed position. The assembly 150 may include a spring 160 that biases the valve 156 into the closed position.

[0008] The valve assembly 150 includes a first pin 152 and a pair of second pins 154 that push a valve 156 into an open position. The pins 152 and 154 press against a valve collar 158 that is attached to said valve 156. The valve collar 158 captures a spring 160 that biases the valve 156 into a closed position. In the preferred embodiment, the first pin 152 has an area approximately four times larger than the combined area of the second pins 154.

[0009] The first pin 152 is located within a pressure chamber 162 of a valve housing 164. The pressure chamber 162 is in fluid communication with a control valve 166. Fluid communication between the pressure chamber 162 and the valve 166 may be provided by a one-way check valve 168 that allows flow into the chamber 162, and an orifice 170 that restricts the flow of fluid out of the pressure chamber 162. The second pins 154 are located within channels 172 that are in fluid communication with the control valve 166. The valve housing 164 has a stop 174 that limits the movement of the first pin 152 so that the valve 156 is initially opened by all of the pins 152 and 154, and then further opened only with the second pins 154.

[0010] The control valve 166 has a pair of cylinder ports 180 that are both coupled to the pressure chamber

162 and channels 172 by a main channel 175. The valve 166 also has a single supply port 182 that is coupled to a source of pressurized fluid and a pair of return ports 184 each coupled to a drain line. The valve 166 can be switched between a first position that couples the cylinder ports 180 to the supply port 182 to allow fluid to flow into the pressure chamber 162 and channels 172, and a second position that couples the cylinder ports 180 to the return ports 184 to allow fluid to flow out of the pressure chamber 162 and channels 172.

[0011] The valve 166 contains a spool 186 that moves within the inner chamber 188 of a housing 190. Within the housing 190 is a first solenoid 192 that can pull the spool 186 to the first position and a second solenoid 194 that can move the spool 186 to the second position. The solenoids 192 and 194 are connected to an external power source which can energize one of the solenoids to move the spool 186 to the desired position.

[0012] In the preferred embodiment, both the housing 190 and the spool 186 are constructed from a magnetic steel such as 440c or 52100. The hysteresis of the magnetic steel is such that the magnetic field within the spool 186 and the housing 190 will maintain the position of the spool 186 even when the solenoid is de-energized. The magnetic steel allows the valve to be operated in a digital manner, wherein one solenoid is energized for a predetermined time interval until the spool 186 is adjacent to an inner surface of the housing 190. Once the spool 186 has reached the new position, the solenoid is de-energized, wherein the hysteresis of the magnetic steel material maintains the position of the spool 186.

[0013] The spool 186 has outer grooves 196 that couple the cylinder ports 180 to either the supply port 182 or the return ports 184. The cylinder ports 180 are located on each side of the supply port 182 to dynamically balance the valve 166 when the spool 186 is moved from the first position to the second position. The fluid flowing through the cylinder ports has an associated resultant force that is applied to the spool 186. Placing the ports 180 on each side of the supply port 182 produces resultant fluid forces that are applied to the spool 186 in opposite directions. The opposing forces offset each other so that the fluid forces do not counteract the pulling force of the solenoid 192 on the spool 186. Likewise, the return ports 184 are located on each side of the cylinder ports 182 so that the resultant forces created by the fluid flowing through the return ports cancel each other, thereby preventing a counteracting force from impeding the pulling force of the solenoid 194. The port locations of the valve thus provide a fluid control valve that is dynamically pressure balanced. Balancing the spool 186 increases the response time of the valve and reduces the energy required by the solenoids to pull the spool 186 from one position to another.

[0014] The spool 186 has an inner channel 198 and a pair of end openings 200 that are in fluid communication with the inner chamber 188 of the housing 190. The end openings 200 and inner channel 198 allow fluid within the inner chamber 188 to flow away from the end of the spool 186, when the spool 186 is pulled to a new position. By way of example, when the second solenoid 194 pulls the spool 186 toward the housing 190, the fluid located between the end of the spool 186 and the housing 190 flows into the inner channel 198 through the end opening 200. The flow of fluid prevents a build-up of hydrostatic pressure which may counteract the pull of the solenoid. The inner channel 198 and end openings 200 thus statically pressure balance the spool 186.

[0015] The valve 166 may have a pressure relief valve 202 that releases fluid when the fluid pressure within the inner chamber 188 exceeds a predetermined value. The relief valve 202 may have a ball 204 that is biased into a closed position by a spring 206. The relief valve 202 may also have an insert 208 with an outlet port 210. The ends of the spool and,the inner surface of the housing may have chamfered surfaces 212 to increase the volume of the inner chamber 188 between the spool 186 and the housing 190 and reduce the hydrostatic pressure within the valve 166.

[0016] In operation, a digital pulse is provided to the control valve 166 to switch the valve 166 and allow a pressurized working fluid to flow into the pressure chamber 162 and channels 172. The pressurized fluid exerts a force onto the pins 152 and 154 which push the valve 156 into the open position.

[0017] As shown in Figure 2, the stop 174 prevents further movement of the first pin 152 while the second pins 154 continue to push the valve 156 into the fully opened position. To close the valve 156, a digital pulse is provided to switch the control valve 166 to couple the pressure chamber 162 and channels 172 to drain. The force of the spring 160 pushes the valve back to the closed position. The orifice 170 restricts the flow of working fluid out of the pressure chamber 162 and reduces the speed of the valve 156 back to the closed position. The orifice 170 provides a damping function which prevents the valve 156 from "banging" against the valve seat. The damping of the valve reduces the wear and increases the life of the valve seat 214.

[0018] The dual pin valve assembly 150 is particularly desirable for use as an exhaust valve. During the exhaust stroke of an internal combustion engine the pressure within the combustion chamber 216 is relatively high. The work provided by the hydraulic fluid must be great enough to overcome the combustion chamber pressure and open the valve. When the valve 150 is initially opened, the exhaust gases within the combustion chamber flow out into the exhaust manifold 218. The flow of exhaust gas into the exhaust manifold 218 rapidly reduces the pressure within the combustion chamber 216. Because of the lower combustion chamber pressure and the momentum of the valve, the hydraulic fluid does not have to provide as much work to continue to open the valve 156.

[0019] The effective area and resulting forces provided by the hydraulic fluid onto the pins is reduced when

the first pin 152 reaches the stop 174. Consequently the work provided by the hydraulic fluid is lowered after the valve 156 is initially opened. The valve assembly of the present invention thus reduces the work and increases the energy efficiency of the engine. Although each incremental reduction of work during one exhaust stroke is relatively small, when multiplied by the number of strokes during the operation of an engine the resultant increase in energy efficiency can be relatively significant.

[0020] Figure 3 is an alternate embodiment of a valve assembly which has a four-way control valve 166'. The control valve 166' is connected to the pressure chamber 162 and channels 172, and a return chamber 220. The return chamber 220 receives pressurized working fluid that pushes the valve 156 back to the closed position. In operation, the valve 156 is switched to couple the pressure chamber 162 and channel 172 to the high pressure fluid, and the return chamber 220 to drain. The pressurized working fluid exerts a force on the pins 152 and 154 which move the valve 156 to the open position. The control valve 166' is then switched to connect the return chamber 220 to the pressurized working fluid, and the pressure chamber 162 and channels 172 to drain. The working fluid within the return chamber 220 pushes the valve 156 back to the closed position. The control valve '166 is preferably dynamically and statistically pressure balanced to increase the valve speed and reduce the energy consumed by the valve.

Claims

1. A valve assembly (150) for an internal combustion engine, comprising:

   a valve (156) that moves between an open position and a closed position;
   a first pin (152) that receives hydraulic pressure to push said valve into the open position;
   a second pin (154) that receives hydraulic pressure to push said valve into the open position; and,
   a valve housing which has a stop (174) that limits the movement of said first pin so that said valve is initially opened by said first and second pins and then further opened by said second pin.

2. The valve assembly as recited in claim 1, wherein said first pin has a larger area than an area of said second pin.

3. The valve assembly as recited in 1 or 2, further comprising an orifice to restrict a flow of fluid from said first pin when said valve moves to the closed position.

4. The valve assembly as recited in any one of claims 1 through 3, further comprising a valve collar (158) coupled to said valve, wherein said first and second pins push against said valve collar.

5. The valve assembly as recited in any one of claims 1 through 3, further comprising an hydraulic valve (166) that provides hydraulic pressure to said first and second pins.

6. The valve assembly as recited in 5, wherein said hydraulic valve is a four-way valve that further provides hydraulic pressure to said valve collar to push said valve into the closed position.

7. A method comprising:

   providing hydraulic pressure to a first pin (152) and a second pin (154) for opening a valve (156) of an internal combustion engine until said first pin reaches a stop (174); and
   providing hydraulic pressure to said second pin for further opening said valve.

8. The method of claim 7, further comprising providing hydraulic pressure to a valve collar (158) for closing said valve.

9. The method of claims 7 or 8, further comprising restricting a flow of fluid from said first pin when said valve moves to the closed position.

Patentansprüche

1. Ventilbaugruppe (150) für eine Brennkraftmaschine, umfassend:

   ein Ventil (156), das sich zwischen einer offenen Stellung und einer geschlossenen Stellung bewegt;
   einen ersten Kolben (152), der hydrostatischen Druck aufnimmt, um das Ventil in die offene Stellung zu drücken;
   einen zweiten Kolben (154), der hydrostatischen Druck aufnimmt, um das Ventil in die offene Stellung zu drücken; und
   ein Ventilgehäuse, das einen Anschlag (174) aufweist, der die Bewegung des ersten Kolbens begrenzt, so dass das Ventil zunächst durch den ersten und den zweiten Kolben geöffnet und dann durch den zweiten Kolben weiter geöffnet wird.

2. Ventilbaugruppe nach Anspruch 1, bei welcher der erste Kolben eine Fläche aufweist, die größer ist als eine Fläche des zweiten Kolbens.

3. Ventilbaugruppe nach Anspruch 1 oder 2, weiter umfassend eine Öffnung, um einen Fluiddurchluss von dem ersten Kolben zu beschränken, wenn sich das Ventil in die geschlossene Stellung bewegt.

4. Ventilbaugruppe nach einem der Ansprüche 1 bis 3, weiter umfassend einen mit dem Ventil verbundenen Ventilbund (158), wobei der erste Kolben und der zweite Kolben gegen den Ventilbund drükken.

5. Ventilbaugruppe nach einem der Ansprüche 1 bis 3, weiter umfassend ein Hydraulikventil (166), das hydrostatischen Druck für den ersten und den zweiten Kolben bereitstellt.

6. Ventilbaugruppe nach Anspruch 5, bei der das Hydraulikventil ein Vierwegeventil ist, das weiter hydrostatischen Druck auf den Ventilbund bewirkt, um das Ventil in die geschlossene Stellung zu drücken.

7. Verfahren, umfassend:

   Erzeugen von hydrostatischem Druck auf einen ersten Kolben (152) und einen zweiten Kolben (154) zum Öffnen eines Ventils (156) einer Brennkraftmaschine, bis der erste Kolben einen Anschlag (174) erreicht; und
   Bereitstellen von hydrostatischem Druck auf den zweiten Kolben zum weiteren Öffnen des Ventils.

8. Verfahren nach Anspruch 7, weiter umfassend das Erzeugen von hydrostatischem Druck auf einen Ventilbund (158) zum Schließen des Ventils.

9. Verfahren nach Anspruch 7 oder 8, weiter umfassend das Beschränken eines Fluiddurchflusses von dem ersten Kolben, wenn sich das Ventil in die geschlossene Stellung bewegt.

Revendications

1. Actionneur (150) pour un moteur thermique interne, comprenant :

   une valve (156) qui se déplace entre une position ouverte et une position fermée ;
   un premier axe (152) qui reçoit une pression hydraulique pour pousser ladite valve dans la position ouverte ; en outre
   un deuxième axe (154) qui reçoit une pression hydraulique pour pousser ladite valve dans la position ouverte ; et
   un logement de valve qui possède une butée (174) qui limite le mouvement dudit premier axe de telle sorte que ladite valve soit initialement ouverte par lesdits premier et deuxième axes puis encore ouverte par le deuxième axe.

2. Actionneur selon la revendication 1, dans lequel ledit premier axe possède une surface plus grande qu'une surface dudit deuxième axe.

3. Actionneur selon la revendication 1 ou 2, comprenant en outre un orifice pour restreindre un écoulement de fluide à partir dudit premier axe lorsque ladite valve se déplace vers la position fermée.

4. Actionneur selon l'une quelconque des revendications 1 à 3, comprenant en outre un collier de valve (158) couplé à ladite valve, dans lequel lesdits premier et deuxième axes sont poussés contre ledit collier de valve.

5. Actionneur selon l'une quelconque des revendications 1 à 3, comprenant en outre un actionneur hydraulique (166) qui fournit une pression hydraulique auxdits premier et deuxième axes.

6. Actionneur selon la revendication 5, dans lequel ledit actionneur hydraulique est un actionneur à quatre voies qui fournit en outre une pression hydraulique audit collier de valve pour pousser ladite valve dans la position fermée.

7. Procédé comprenant :

   la fourniture d'une pression hydraulique à un premier axe (152) et un deuxième axe (154) pour ouvrir une valve (156) d'un moteur thermique interne jusqu'à ce que ledit premier axe atteigne une butée (174); et
   la fourniture d'une pression hydraulique audit deuxième axe pour ouvrir en outre ladite valve.

8. Procédé selon la revendication 7, comprenant en outre la fourniture d'une pression hydraulique à un collier de valve (158) pour fermer ladite valve.

9. Procédé selon les revendications 7 ou 8, comprenant en outre la restriction d'un écoulement de fluide à partir dudit premier axe lorsque ladite valve se déplace vers la position fermée.

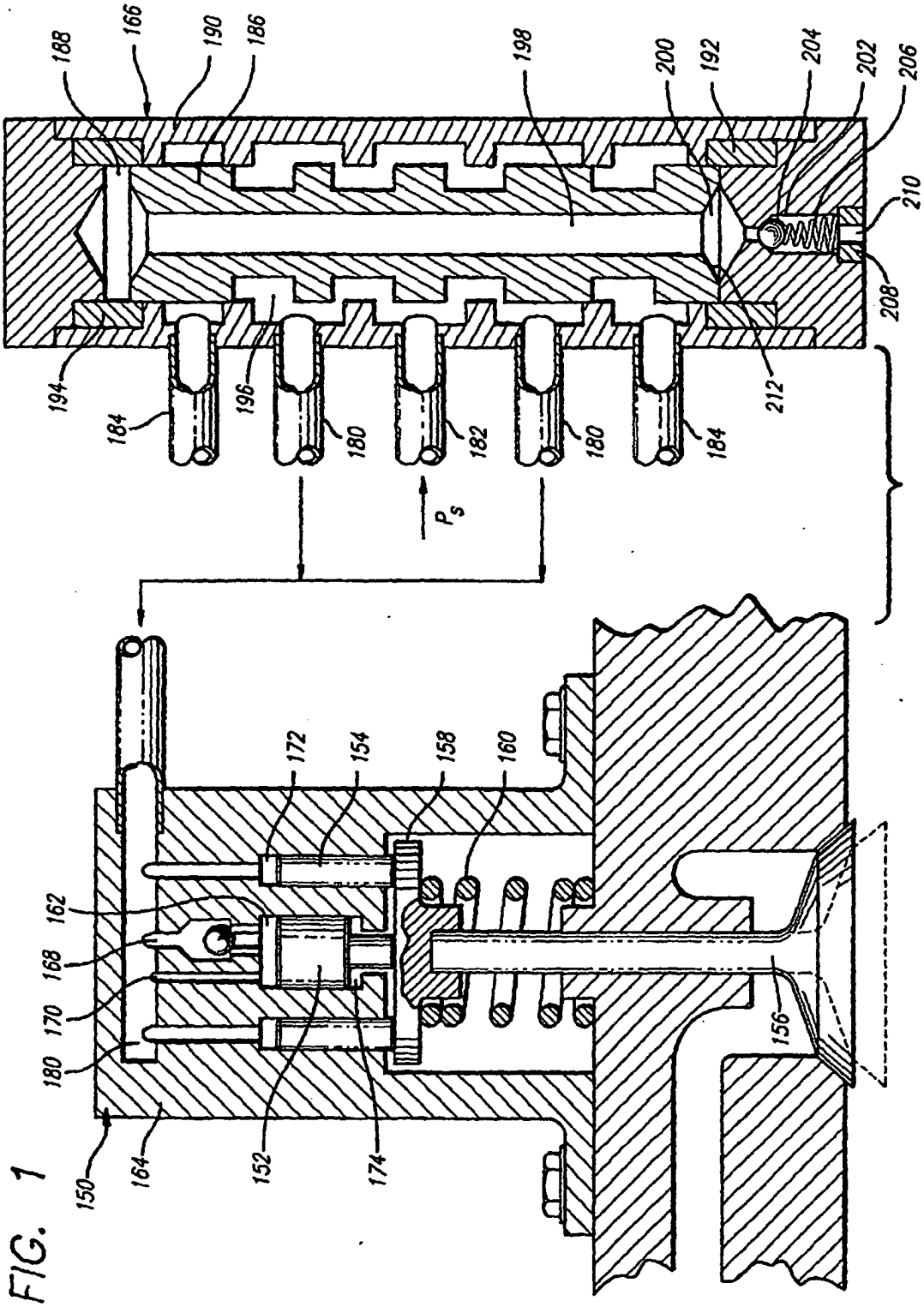
188
166
190
186
198
200
192
204
202
206
210
208
212
194
196
184
180
182
180
184
P_s
172
154
158
160
162
168
170
180
156
150
164
152
174

FIG. 1

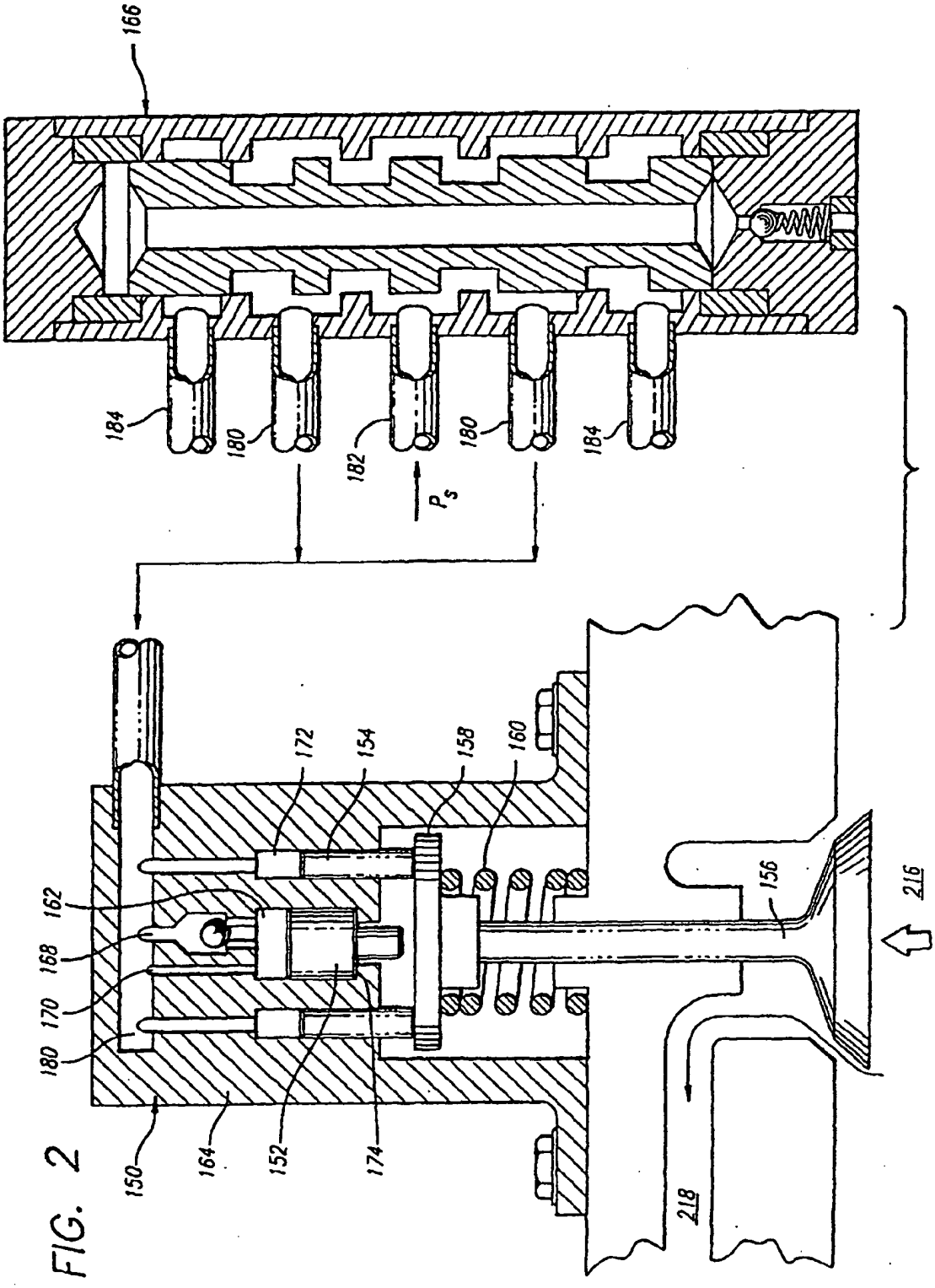
166
184
180
182
180
184
P_s
172
154
158
160
162
168
170
180
156
216
150
164
152
174
218

FIG. 2

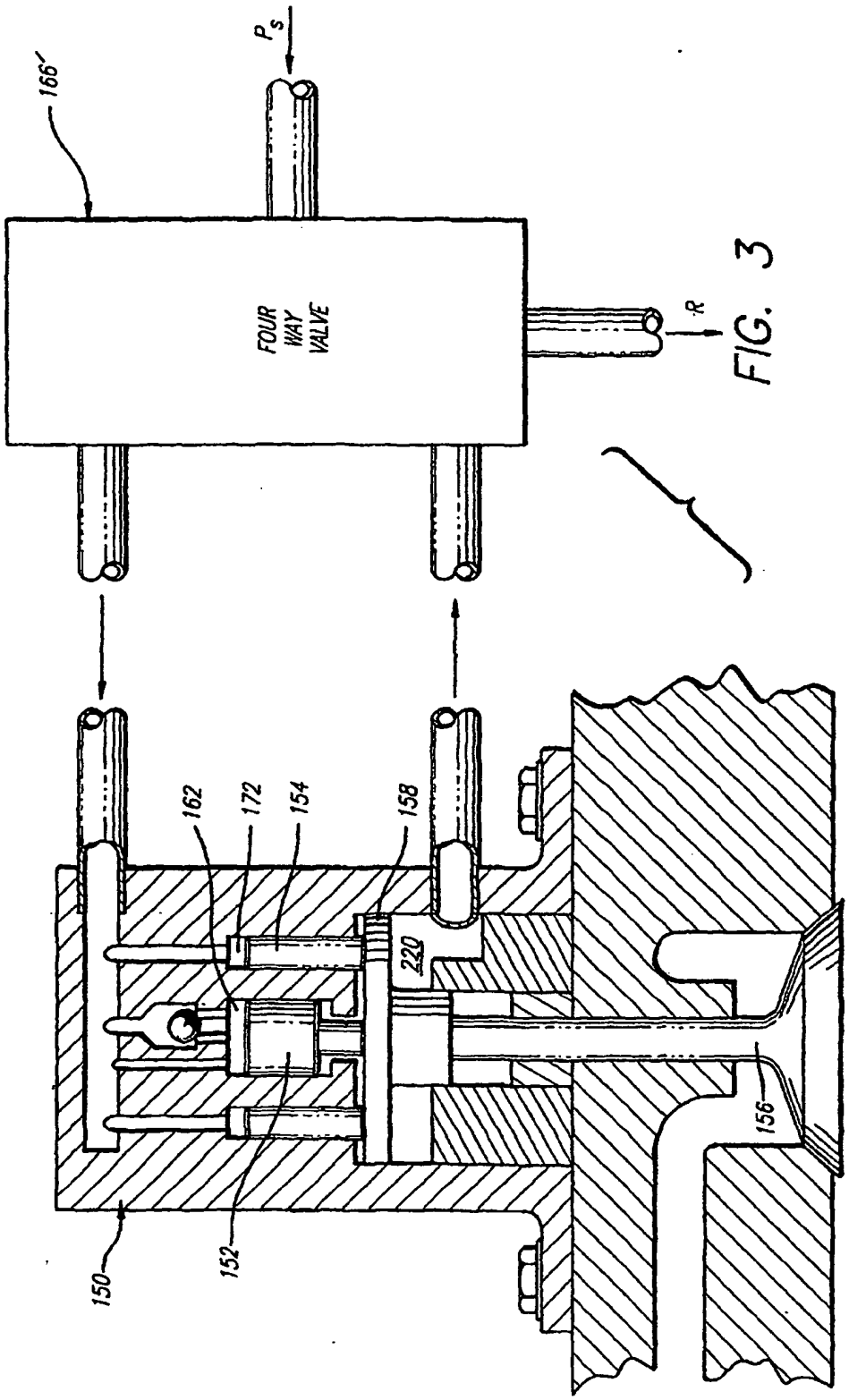

FIG. 3